Estimation of Potential National Benefits of Advanced Fueling Infrastructure Deployment (AFI Task 1)

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April 20, 2018

Project Overview

Timeline

- Project start: Oct. 2017
- Project end: Sept. 2018
- Completion: 60%

Budget

	FY18
ANL	$135K
NREL	$50K
ORNL	$50K

** Funding amount by lab is for this task only, not for the entire pillar*

Barriers

- Infrastructure has long been a major barrier to alternative fuel vehicle (AFV) adoption
- Accurately measuring the transportation system-wide energy impacts of electrified shared mobility with infrastructure support

Partners

Argonne National Laboratory · NREL National Renewable Energy Laboratory · Oak Ridge National Laboratory

Project Overall Objectives/Relevance

Task 1 under Advanced Fueling Infrastructure Pillar

Quantify the national energy impact of ride-hailing PEVs as compared with privately owned PEVs assuming different infrastructure support (e.g. Level 2, DCFC, high power FC)

- ❑ Understand national energy impacts of PEVs with full infrastructure support as compared with shared ICEs
- ❑ Understand national energy impacts of shared PEVs (with full infrastructure support) vs. only privately owned PEVs

Interdependencies between Tasks

Inputs Needed

Regional EVSE Deployment

AFI Task 2.1

AFI Task 2.3

This Project

AFI Task 1
National Impact

Shared mobility adoption/usage

Other Inputs Needed

Schedule/Milestones

Year	Q	Quarterly Milestone	Progress
FY18	Q1	*Preliminary estimates of national energy impacts of electrified shared mobility (ANL)*	Completed
	Q3	Report on regional results with HPFC (NREL)	In Progress
	Q4	Report on market penetration scenario analysis (ORNL)	In Progress

Overall Approach: Utilize multi-lab sophisticated tools and database

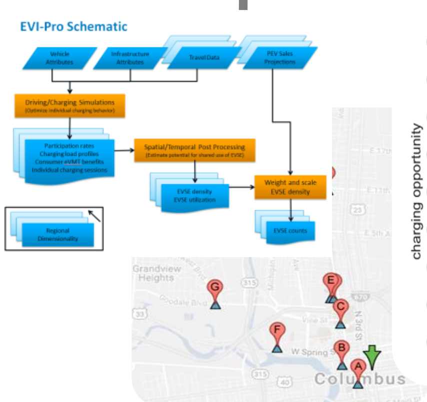
Charging Infrastructure Scenarios
- Locations of Charging Stations
- Number of chargers per station

Charging Opportunity
- Probability of finding a charging station at a stop

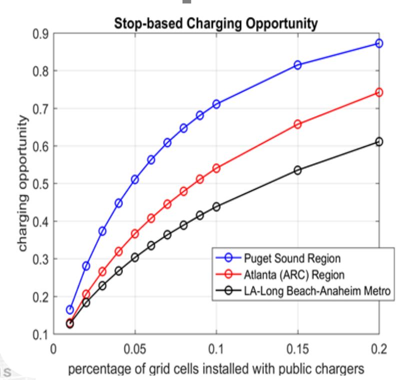
Extended Electric Vehicle Range
- Recharging at charging stations can extend electric vehicles' range

Vehicle Market Share
- Sale & Fleet Size: SI/CI/HEV/ PHEV/BEV

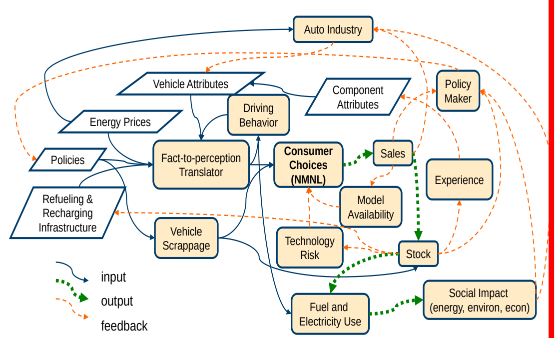
Energy Use & VMT by Fuel, vehicle Type
- Energy use by fuel type
- GHG
- VMT and eVMT



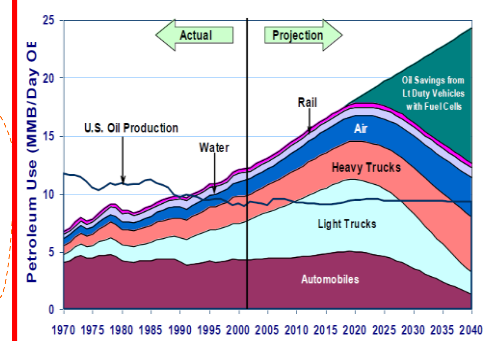
EVI-Pro Model



Charging opportunity Model



MA3T Model



VISION Model

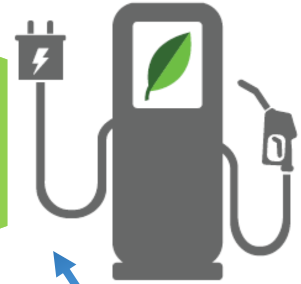
Several iterations conducted

U.S. DEPARTMENT OF ENERGY SMARTMOBILITY Systems and Modeling for Accelerated Research in Transportation

Argonne NATIONAL LABORATORY · INL Idaho National Laboratory · BERKELEY LAB · OAK RIDGE National Laboratory · NREL NATIONAL RENEWABLE ENERGY LABORATORY

Overall Analysis Process/Methodology

Fuel Use



Change in Adoption
- Higher PEV adoption
- Lower private vehicle adoption

Change in Efficiency
- Higher MPGGE than using ICEVs
- PHEV: higher eVMT% with EVSE

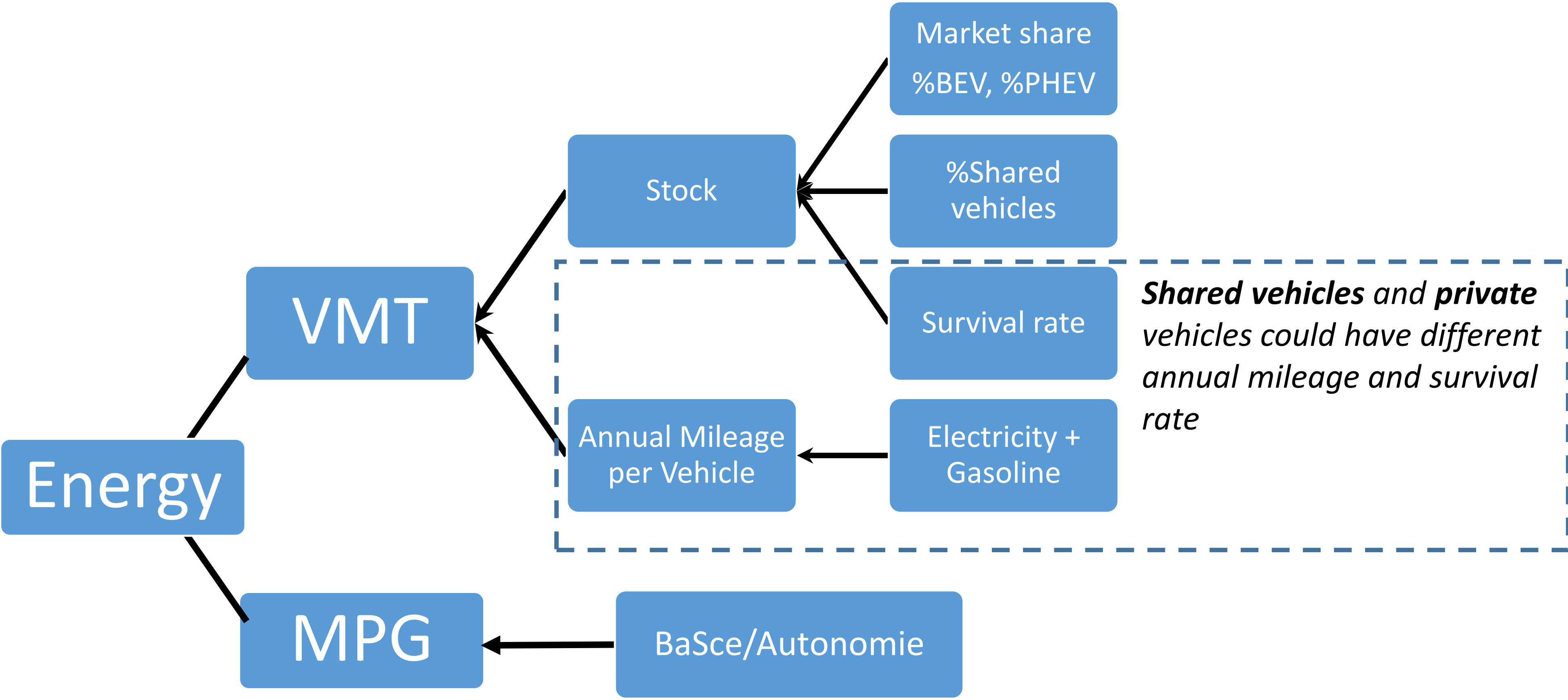
Change in VMT
- Reduced personal vehicle miles
- Increased shared vehicle miles
- Shorter shared vehicle lifetime

$$\text{Annual Fuel Use} = \frac{VMT_{BEV100}}{MPG_{BEV100}} + \frac{VMT_{BEV200}}{MPG_{BEV200}} + \frac{VMT_{PHEV20}}{MPG_{PHEV20}} + \frac{VMT_{PHEV50}}{MPG_{PHEV50}} + \cdots + \frac{VMT_{ICE}}{MPG_{ICE}},$$

$$\text{Annual Fuel Use} = \frac{VMT\ Ride\ Hailing}{MPG\ Ride\ Hailing} + \frac{VMT\ Car\ Sharing}{MPG\ Car\ Sharing} + \frac{VMT\ Ride\ Sharing_0}{MPG\ Ride\ Sharing} + \frac{VMT\ private}{MPG\ Private},$$

Analysis Process/Methodology: VMT and Efficiency

Focus: quantify impacts of sharing on vehicle annual mileage and survival

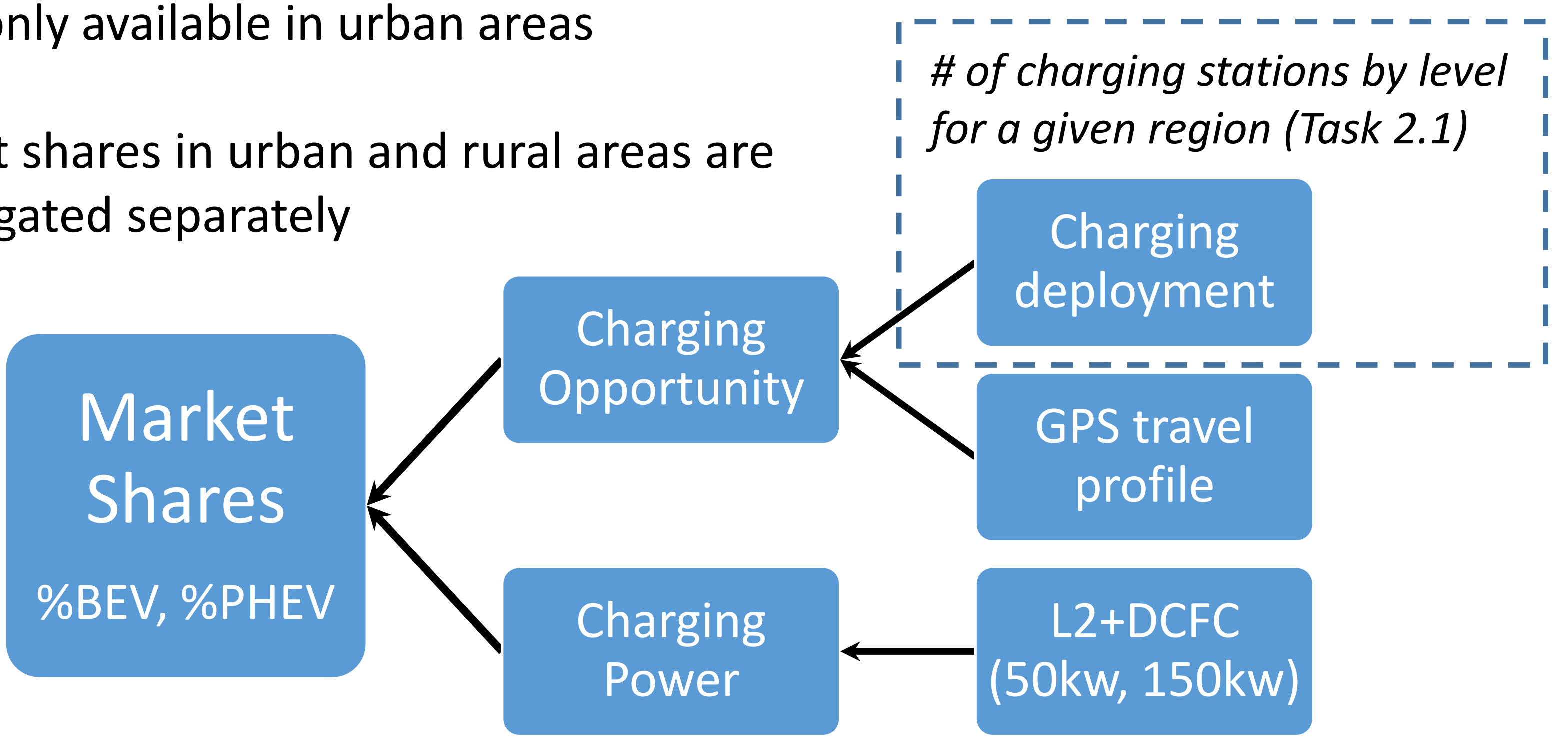


Analysis Process/Methodology: Market Shares

Focus: quantify impacts of charging opportunity and efficiencies on PEV adoption

Increased charging deployment is assumed to be only available in urban areas

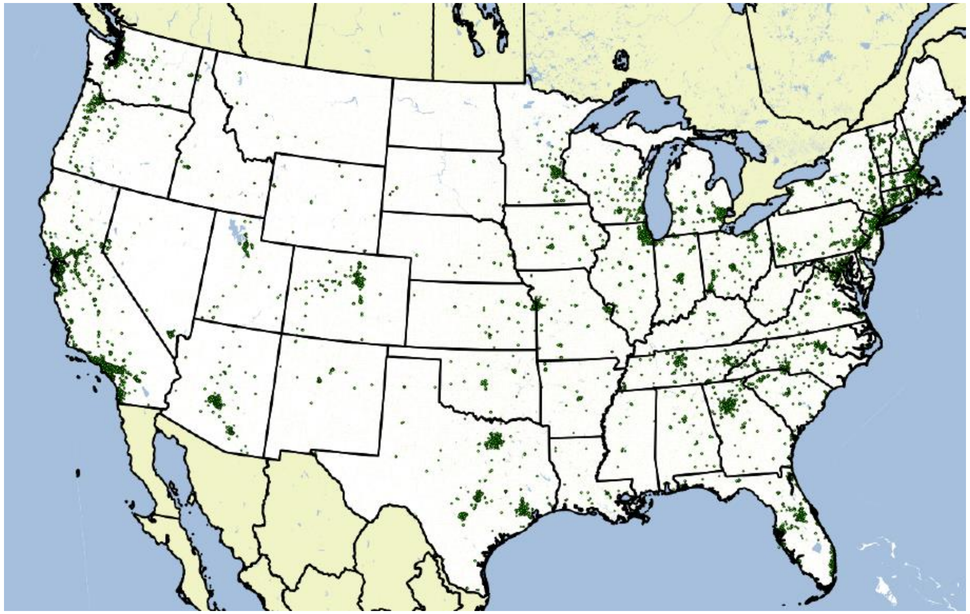
Market shares in urban and rural areas are investigated separately



* Other factors that could affect PEV adoption are already included in MA3T model, but are not listed here

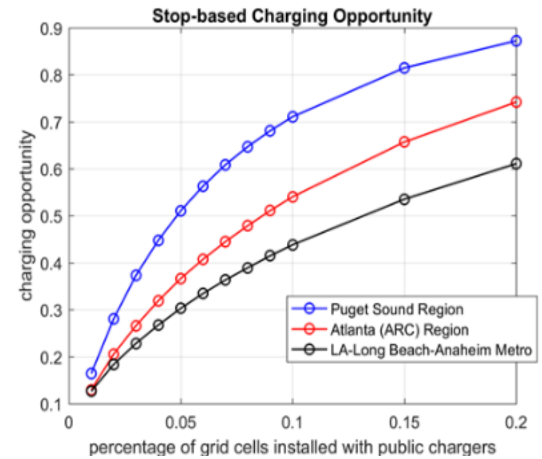
Charging Availability-Opportunity is Estimated Based on Charging Coverage from Regional Simulation Results

Public charging station map



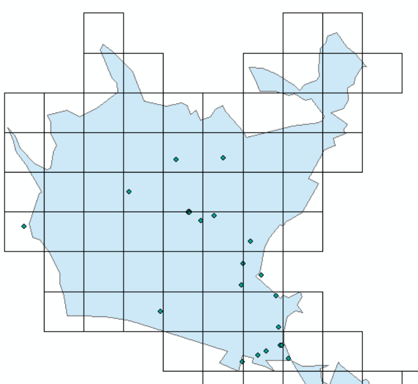
Source: (Wood et al., 2017)

Charging availability-opportunity model (3 curves)



Source: (Liu et al., 2017)

Charging Coverage



1×1 mile cells

$$\frac{\text{\# of cells with chargers}}{\text{total \# of cells}}$$

Charging opportunity: probability of finding a nearby charger at a stop (used by MA3T to estimate extended range and market share)

Impacts of Sharing Mobility on Ownership and Annual VMT are Very Sensitive To Sample Size and Optimization Goals

- **Columbus** Study (AFI Task 2) used a heuristic method and shows:
  - 5% vehicles could be replaced with 3.5% more VMT increase due to 'deadheading' trips
  - The eVMT% (PHEV) after infrastructure deployment: 5%- 15% improvement
- **Chicago** (following the same emulation rules used in Columbus) shows different results
- **Results are very sensitive to sample size and optimization goals**
  - minimize dead head trips,
  - minimize total vehicle miles traveled,
  - minimize # of shared vehicles needed
- ***Analysis is needed for more locations to better estimate the national impact***

National Impact Analysis: Inputs and Assumptions

- Analysis horizon: 2017 -2030 (estimate short-term impact)
- Analysis scope: ride hailing in urban area (areas with population more than 50,000)
- PEV ranges: BEV100/300, PHEV20/50
- **Market Adoption**: MA3T (ORNL) projects market shares of PHEV and BEV based on simulated infrastructure availability and power (EVI-Pro, NREL)
- **Efficiency**: EVI-Pro simulates **eVMT%** improvement with infrastructure support

Vehicle	No infra.	With infra.
PHEV20	23.0%	63.9%
PHEV50	70%	86.6%
PHEV20SUV	23%	63.6%

- **VMT**: annual $\text{VMT/Veh}_{\text{shared}}$ = 5 times of annual $\text{VMT/Veh}_{\text{personal}}$
- Charging power and availability (definition could be found in slide 11)

Scenario Name	2017		2030	
	Charging Availability	Ave. Power (KW)	Charging Availability	Ave. Power (KW)
Current	5.3%	11.4	5.3%	11.4
EVI-pro	5.3%	11.4	15.2%	55.9
EVI-pro+AllDCFC	5.3%	11.4	15.2%	150

Note: Increased charging availability only in urban area, data from alternative fuel data center

Other Major Assumptions

- Total vehicle ownership: AEO 2017 projections (reference case)
- Vehicle adoption: $\%Veh_{personal}$ = 2 times of Veh_{shared}
- Future vehicle efficiency (MPGGE) and vehicle cost: VTO BaSce Analysis
- %Veh adoption and %VMT in urban area
  - *Population 50,000 or more: **479** regions/cities (exclude cities in PR)*
  - *Population 500,000 or more: **79** regions/cities (exclude cities in PR)*
  - *Population 1,000,000 or more: **41** regions/cities (exclude cities in PR)*

Population	Vehicle %	VMT %	Pop%
50,000 - 199,999	10.0%	9.6%	72.2%
200,000 - 499,999	8.4%	7.4%	
500,000 - 999,999	7.7%	7.6%	
1 million or more	34.6%	33.8%	
Non-Urban	39.2%	41.7%	
Unknown	0%	0%	
Total	100%	100%	

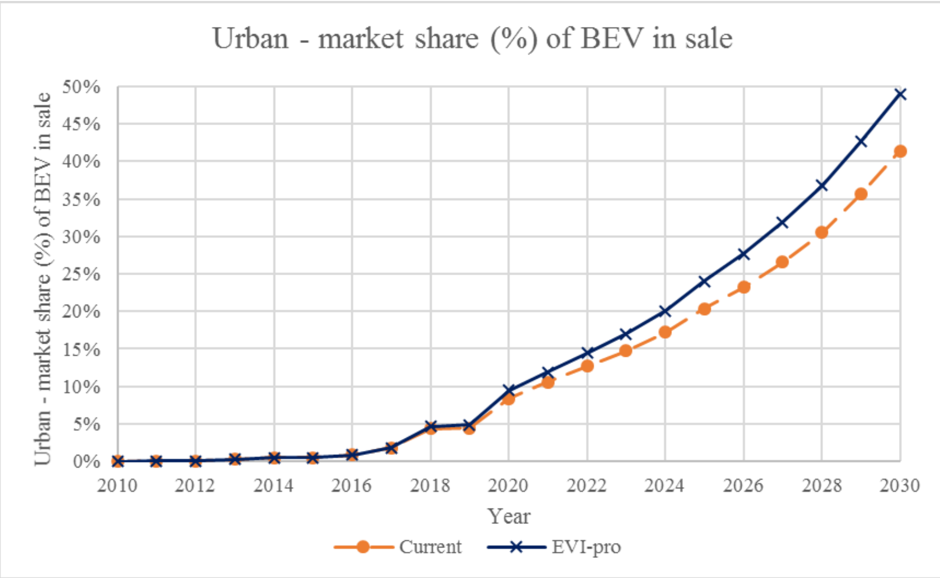
Source: Highway Statistics, National Household Travel Survey, U.S. Census
Note: Columbus, Ohio has a population over 1M

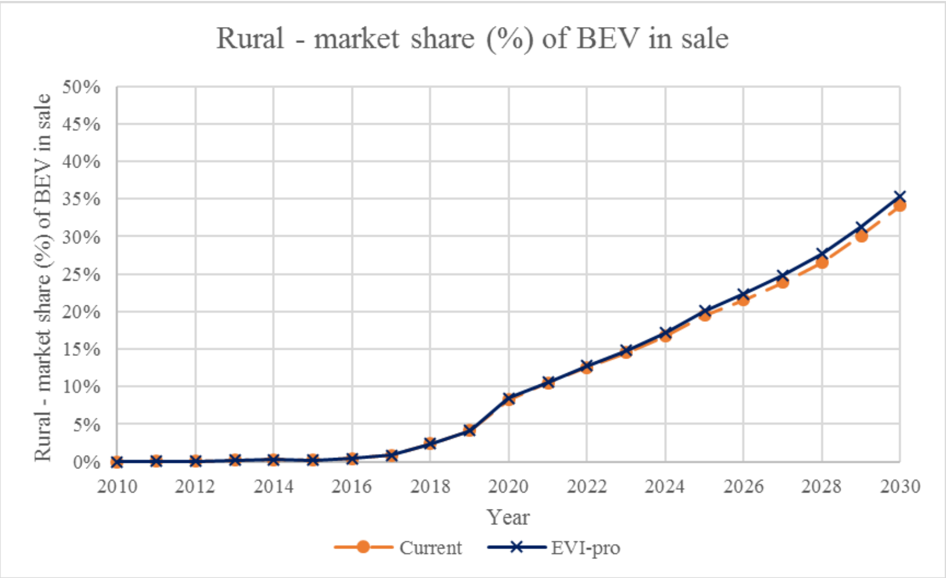
Sensitivity Analysis

- Sensitivity Analysis
  - **VMT**: annual $\text{VMT/Veh}_{\text{shared}}$ = 3-8 times of annual $\text{VMT/Veh}_{\text{personal}}$
  - **Adoption**: $\%\text{Veh}_{\text{personal}}$ = 1-4 times of $\text{Veh}_{\text{personal}}$
  - **Urban area**: 500,000 or more population, 52% of total population
  - **Charging power and changing time (see table below)**

	Term	Definition
Impacts of charging availability-opportunity relationship	Average estimate	The average of the three charging availability-opportunity relationship curves (baseline), **see slide 11 for details**
	Low estimate	The low estimate curve of the charging availability-opportunity relationship (LA data); Certain charging availability level will yield lower charging opportunity than the average scenario.
	High estimate	The high estimate curve of the charging availability-opportunity relationship (Seattle data) Certain charging availability level will yield higher charging opportunity than the average scenario.
Impacts of available charging time	2 hours	Each driver has an average of 2 hours' available time for charging EV in public areas (baseline, NHTS 2009 data)
	1 hour	Each driver has an average of 1 hour' available time for charging EV in public areas
	0.5 hour	Each driver has an average of 0.5 hours' available time for charging EV in public areas

PEV Market Penetration with Infrastructure Support



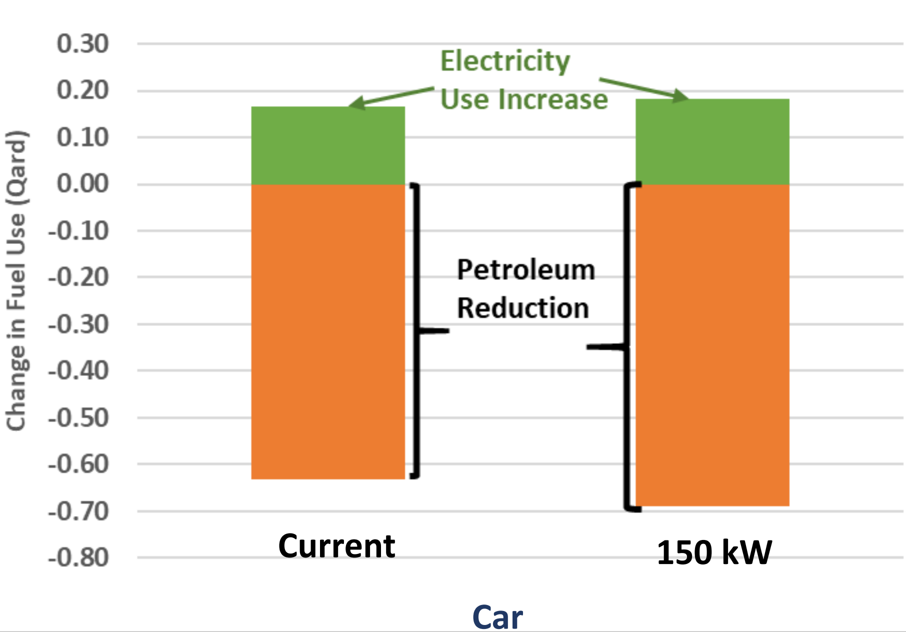


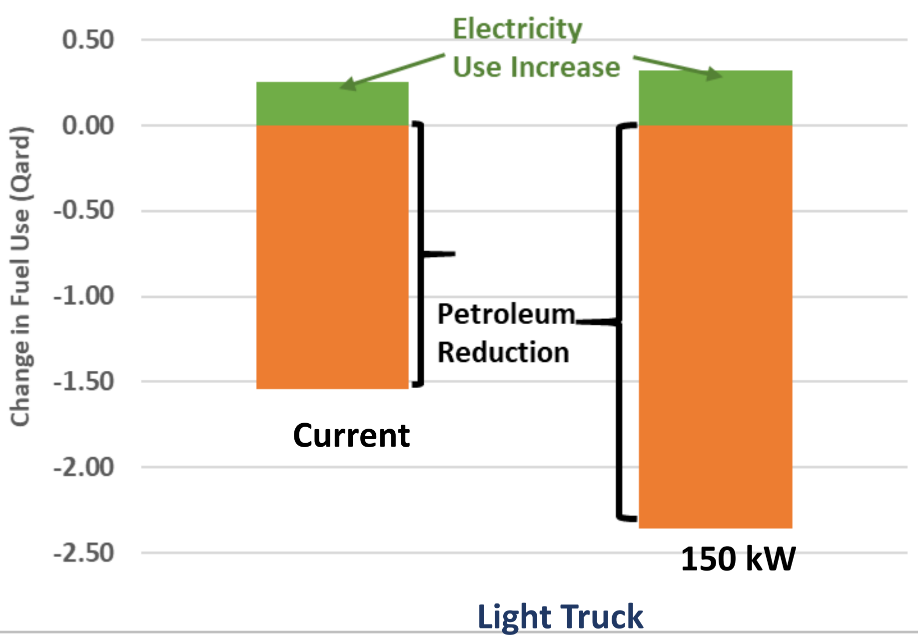
Findings – with charging infrastructure in urban areas:

1. Mainly stimulate BEV market in urban areas, and slightly increase BEV share in rural areas
2. Change the relative competitiveness of BEV between urban and rural areas
3. Market increase in “Current” scenario mainly due to decreased battery cost and vehicle cost

Total LDV Energy Use Could Be Reduced By 0.93 Quad In 2030 with Infrastructure Support

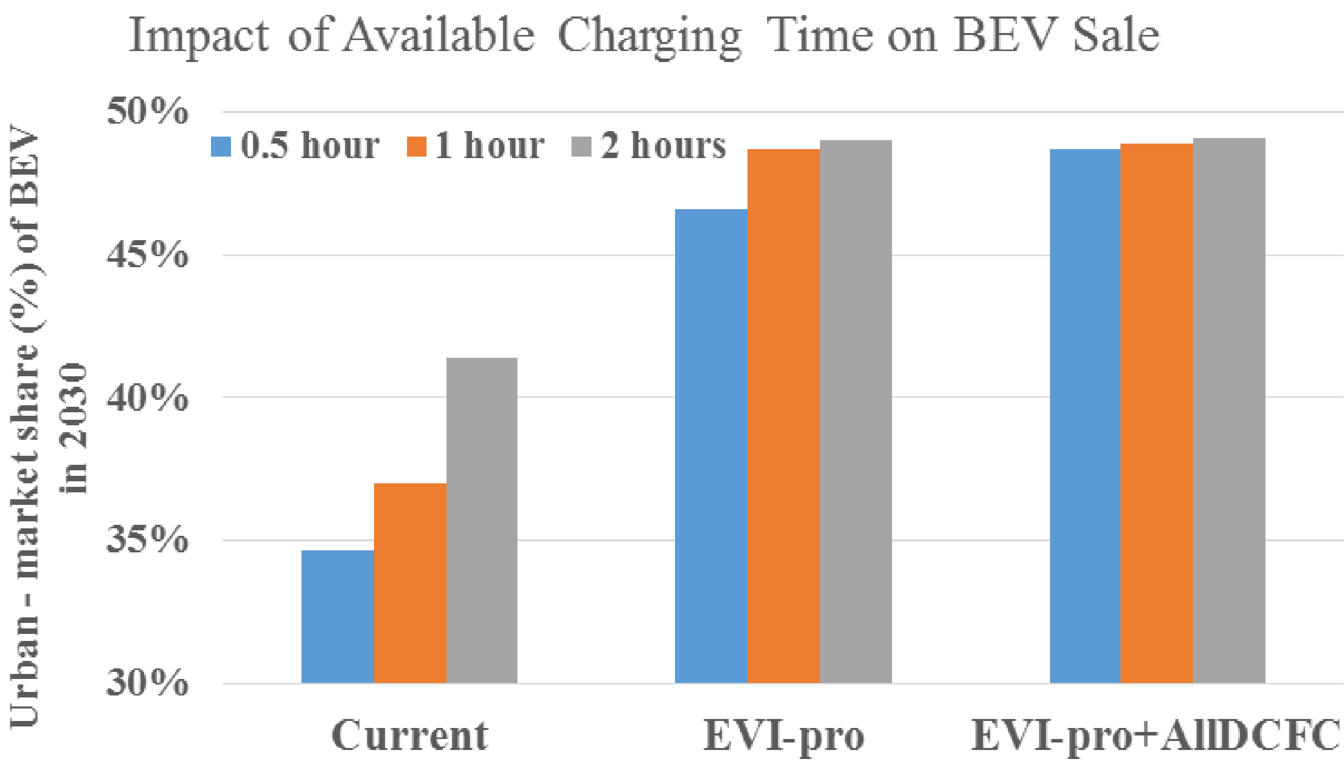
- Total LDV energy use could be reduced by 0.76 quad in 2030 even with current infrastructure deployment
- Increase infrastructure availability to support shared mobility could further reduce 0.18 quad energy use (total reduction: 0.93 quad) annually
- Total petroleum reduction is about 2.2 quad with current infrastructure deployment, could be further reduced by 0.8 quad with increased infrastructure availability





Sensitivity Analysis: Impact of DCFC on BEV Adoption

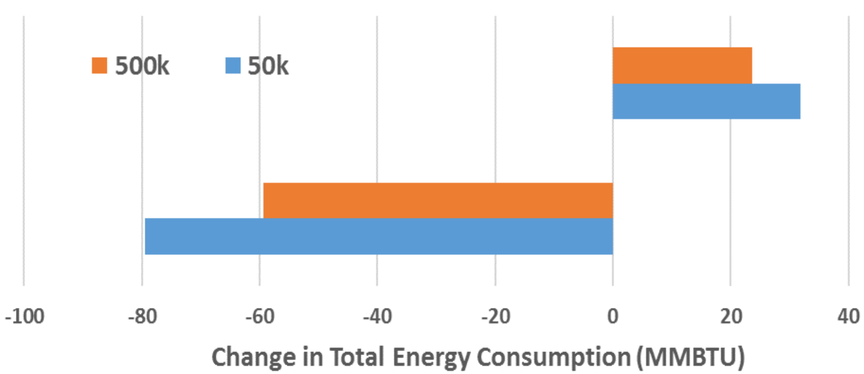
- To further evaluate the benefits of DCFC, senario "EVI-pro+AllDCFC" assumes an average of 150 KW charging power in 2030.
- The higher charging power in the "EVI-pro+AllDCFC" scenario does not offer much larger market share comparing to “EVI-Pro” which consider 50 KW average charging power
- However, the "EVI-pro+AllDCFC" has the best performance in mitigating impacts of shorter charging time.

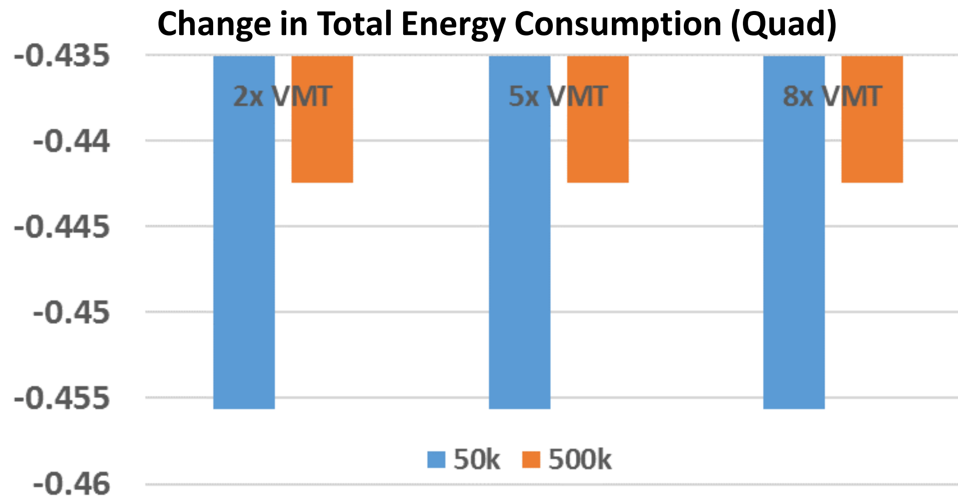


Sensitivity Analysis: Energy Impact

Annual energy consumption reduction is not very sensitive to how many times the ride haling vehicle is driven annually comparing to the personal vehicle

(when assuming fixed VMT demand in the future, no VMT reduction or increase due to sharing)





50K: Urban areas with >50K pop.
500k: Urban areas with >500K pop.

EVI-Pro Scenario: Car

Planned/Proposed Future Work

- Estimate national level impact based on AFI Task 2 regional EVSE deployment findings and electrified shared mobility market adoptions
- Analyze regional variation of real-world electric range, charging efficiency, electricity cost and estimate their impact on regional adoption of electrified ride-hailing
- Provide a framework to estimate spatial and temporal variation of charging demand based on electrified shared mobility adoption and behavior, charging station operational characteristics, and regional fuel/electricity supply, etc.
- Quantify national energy impacts and analyze sensitivities to key parameters:
  - Shared mobility usage (e.g., % of shared vehicles, rides, miles)
  - Shared and privately owned vehicle adoption rates
  - Different system optimization goals (e.g. minimize dead head trips, minimize total vehicle miles traveled, minimize # of shared vehicles needed)

Summary

- Objective: Quantify the national energy impact of ride-hailing PEVs as compared with privately owned PEVs assuming different infrastructure support
- BEV market penetration could reach 50% in urban areas when infrastructure availability increased from 5.3% (2017 level) to 15.3% in 2030
- Total LDV energy use could be reduced by 0.93 quad in 2030 with increased infrastructure availability supporting increasing ride hailing vehicles
- If shared mobility does not change total VMT and vehicle ownership, energy impact is minor. Key Research Questions are:
  - How much is a ride hailing vehicle driven vis a vis a private vehicle,
  - How many shared vehicles are adopted,
  - How many private vehicles are displaced

Considering the changes in each of these key questions, whether there is a spatial and temporal difference in charging demand which results different charging deployment → Energy Impact

Response to Reviewers' Comments

Reviewer comment	PI responses
The reviewer noted that the approach seems mostly fine; however, the reviewer was confused about the connection between Task 1, which states, "impacts of near-term AFV infrastructure," yet the research seems to be 100% electric vehicles (EVs). The reviewer stated that if the task was not fully fulfilled, it should change to only include EVs. AFVs are considered to be hydrogen fuel cells, biodiesel, propane, CNG, etc. The reviewer said that some might even categorize EVs as something other than AFVs because they would not consider electricity a "fuel."	The study scope is decided by the team with guidance from DOE sponsors. FY17 focus on plug-in electric vehicles (PEV) used as ride hailing vehicles. Electricity is considered as an alternative fuel type while electric vehicle is considered as AFV. In the future, we could extend the scope to other alternative fuel types upon DOE approval.
The reviewer stated that a possibly missed opportunity in considering the electrification and shared mobility interaction is the third leg of the automated-shared-electric (ASE) triangle, automation. The reviewer noted that automated shared EVs are distinct from non-automated shared EVs in how efficiently they use EVSE and their range.	We agree the interaction between electrification and shared mobility is definitely an important research question. However, this questions is covered under Mobility Decision Science (MDS) pillar. We expect to utilize their results in FY18 and FY19 to develop updated results. Also, for FY17 and FY18, this task focus on men-driven shared mobility. Automated shared EVs are currently investigated by Connected and Automated Vehicle (CAV) pillar.
The reviewer commented that existing charger use data show an aversion to charging away from home both from a convenience perspective and one of cost, and noted that this approach seems to ignore this fact by focusing exclusively on away from home DC fast charging. The reviewer commented that the use of home charging to support home and work trips for ridesharing should have greater consideration in this model.	In FY17, we assumed shared PEVs will start the day fully charged. The regional modeling/simulation (Task 2, now in a separate poster) focusing on identify needed EVSE (L2, 50kw DCFC) deployment in public domain to support shared PEVs. We have further elaborated our study objectives, scope and method this year in more details.
The reviewer pointed out that the approach to this project is flawed and that it makes the overriding assumption that the charging (not "fueling") infrastructure is the primary deterrent to EV adoption.	We have further elaborated our study objectives, scope and method this year in more details. Also, this task is under Advanced Fuel Infrastructure (AFI) pillar. Our main focus is to investigate the impacts of charging availabilities and efficiencies on PEV adoption. However, other factors (e.g., fuel price, battery cost, incentive, and consumer valuation) are also considered in ORNL's MA3T market choice model when projecting future PEV adoption.

Response to Reviewers' Comments (Con't)

Reviewer comment	PI responses
The reviewer noted that looking at national trip purpose segmentation may not reflect urban trip segmentation and suggested that this should be validated. The reviewer also found it unclear whether the model accounted for all trips, or only trips made by car. The reviewer added that home charging and corporate charging would be important to include somehow in this analysis; workplace and home charging account for a significant fraction of EV charging, and might account for shared vehicle charging when a driveway is rented out to an electric Zipcar, for example.	The study focus is trips made by car in both urban and rural areas. We assume the ride hailing will be much more popular in urban areas in short-term so the increasing infrastructure deployment will be in urban area only. However, there is minor increase in PEV adoption in rural areas as well due to the overall increased charging availabilities. Also, in FY17 this study focus on men-driven ride-hailing service, so car sharing service such as Zipcar is not considered. However, we thank reviewer's comments. We will consider it when the scope extended to include car sharing.
The reviewer noted that although the presenter claims to have identified three types of shared mobility, each of these represents a maturing business model that requires more substantial investigation in the various deployment scenarios for each type of shared system before models for any of these three systems would appear to be validated.	We explored the different types of shared mobility in the very early stage of this study to identify which type of mobility service most likely to have significant impacts on VMT and vehicle adoption in short to middle terms. Before conducting simulation and modeling, we first thought ride hailing might reduce the system VMT if demand is the same as before. However, regional simulation results shows the opposite (covered in a different task now) due to deadheading trips. We realized now the research question becomes how much VMT would be increased which highly depending on sample size, rules of ride hailing (e.g. how long the driver willing to drive or wait for next ride) and systems optimization goals (e.g. minimize deadhead trips, # of vehicles needed, etc). We have further revised our research scope and expect to have some results in FY18.
The reviewer said that making progress on a flawed approach is not of value, and noted that it is hard to understand from the presentation what was being accomplished. The reviewer found one of the most glaring flaws in the SMART Mobility projects is the reliance on incomplete and poorly designed experiments that create dubious datasets that industry does not see as being validated. The reviewer further stated that the data used are what is available and are not agreed upon by significant stakeholders as being appropriate to the purpose it is being applied to.	2017 AMR presentation only covers the early stage of the study. After we received reviewers' comments, the team has spent significantly effort to further define study scope and methodology. Also, with more regional simulation results become available, we have better ideas about how to develop a systematic approach to evaluate national impacts. There is very limited data available that could help us to understand the impact of shared mobility. Again, we have further designed the study to examine how VMT and vehicle adoption would change under different given conditions to explore possible outputs (e.g. energy consumption).
The reviewer found this project to be limited to the academic elements within the DOE laboratory system using requested data from a city and charge system operator. The reviewer said that this is extremely limited and will lead to extremely limited conclusions.	There is very limited travel data, especially shared travel data available in public domain that we could utilize. Through collaborating with Smart City, we got the INRIX data (all private vehicles) to emulate shared mobility and identify needed EVSE deployment. In FY18, we will get more regional results (EVSE deployment) from different cities using robust travel datasets including shared travel data (RIdeAustin).

THANK YOU!
QUESTIONS?

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